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Water resources and freshwater ecosystems in Sudan

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Abstract

Sudan is a large country with varying standards of living, culture and climate. When this is superimposed on the multi-sectoral nature of water, coordination of activities in water resources planning, management and development becomes essential. The spirit of cooperation and close cooperation with countries sharing the same water resources should continue, preferably through an institutional cooperative framework for each shared basin. The guiding sprit should be equitable, legitimated, integrated, sustainable and environmentally sound utilisation of the common water resources, without significant harm from one country to another. Some of the issues and problems faced are referred in this article. Sudan has recently taken some major steps to organise the water sector. The article also shows some of the joint efforts to establish and advance cooperation with the Nile basin countries for integrated development of the shared watercourse. It concluded with a future policy look to address the emerging issues. A water policy is bound to be dynamic as it addressed issues with many variables. It is expected that, as time goes on, some new issues will surface while earlier issues will fade out. When this happens, another review of the water sector policy would be appropriate.
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Keywords: Sudan; Water resources; Management and development; Future prospects

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1. Introduction

The water cycle is an integrated and dynamic component of the earth's geophysical system and both affects and is affected by climate conditions. Changes in the earth's radiation balance affect winds, temperatures, atmospheric energy and water transport, cloud dynamics and more. Changes in temperature affect evaporation and transpiration rates, cloud characteristics and extent, soil moisture, and snowfall and snowmelt regimes. Changes in precipitation affect the timing and magnitude of floods and droughts, and shift runoff regimes. Synergistic effects will alter cloud formation, soil and water conditions, vegetation patterns and growth rates [1].

Several authors, politicians, leaders of international organisations and journalists have cautioned the world community that the increasing scarcity of freshwater resources might lead to national and international conflicts. When relating this to climate change forecasts—most of which indicate that climate change will have a significant impact on the availability of freshwater resources, on water quality, and on the demand for water—this is alarming news for humankind as it threatens human security [2].

A water policy is a dynamic process which needs to be reviewed from time to time, taking into consideration the outcome of previous policies, changes in supply and demand parameters, advancement in knowledge and alterations in the surrounding environment. Water policies are complex, as water goes beyond its sector to involve many other sectors and may beyond the international boundaries. Water is an essential factor for the

Table 1
Annual rainfall pattern (10^9 m^3/yr)

Average range (mm)	Annual rainfall	%
<100	41.7	3.8
100–300	76.5	6.9
300–600	199.5	18.2
600–1000	515.5	47.2
>1000	261.0	23.9
Total	1094.2	100.0

development and social welfare of developing countries as it is the key to agriculture, agro-industry, transport and domestic activities. Its importance is felt more when it is scarce, as in arid and semi-arid zones. The major part of Sudan falls within that category. Scarcity of water may be the reason behind the low population density of the country. Nearly all the people gather around water points, being it the Nile or other streams, as water forms the centre for all their activities.

The area of Sudan is 250 million ha. Unfortunately, two-thirds of that area is either arid or semi-arid land with rainfall less than 400 mm annually. Rainfall in most of the remaining third is concentrated in 4 months, with the rest of the year virtually dry. Even in those 4 months, the rain generally comes in isolated showers and varies widely from one year to another (Table 1). Thus, Sudan has to rely on irrigated agriculture to secure food and cash crops.

2. Available water resources

As more than 60% of the area of Sudan lies within the Nile basin, any water that flows to the Nile in that area is considered as part of the Nile waters, of which Sudan can only abstract within its share according to the 1959 Nile Waters Agreement with Egypt. This is limited to $18.5 \times 10^9\,m^3$ as measured in central Sudan, out of $84 \times 10^9\,m^3$ the long-term average annual flow of the Nile. Sudan's share in the Nile waters may be increased by acting with Egypt to reduce evaporation losses from the swamps of the south after due consideration of the environmental effects of such actions. It might also decrease as an effect of climate change and requirements in the upstream reaches. Nine countries share the Nile with Sudan. These are Burundi, Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Tanzania and Uganda. The Nile basin system in Sudan comprises the Blue Nile, Rahad, and Dender system. The White Nile, Bahr El Gabal, Zaraf, Bahr El Ghazal and Sobat. In addition, the Atbara system (Table 2).

Life in Sudan revolves around water, as the major part of the country lies within the arid and semi-arid zones. The total amounts of fresh water from internal and external sources is around $30 \times 10^9\,m^3$/yr [3], bringing the per caput water availability below the water stress limit $1000\,m^3$. Agriculture, the key user of water, dominates the overall economic growth and development of the country. It constitutes 90% of Sudan's exports and contributes about 36% of the GDP. The livelihood of more than 80% of the population depends on agriculture, which employs 61% of the active labour force; the majority are women [4]. If these resources were devoted to agriculture alone, they would irrigate an area of less than

Table 2
Nile waters

Bahr El Gabal	$26 \times 10^9\,m^3$
Bahr El Ghazal	$15 \times 10^9\,m^3$
Sobat at Malakal	$13 \times 10^9\,m^3$
Total at Malakal	$54 \times 109\,m^3$
Losses in swamps	$27 \times 10^9\,m^3$
White Nile at Malakal	$26 \times 10^9\,m^3$
Blue Nile at junction	$53.4 \times 10^9\,m^3$
Atbara system	$11.6 \times 10^9\,m^3$
Losses along river	$77 \times 109\,m^3$
Net available at Aswan	$84 \times 109\,m^3$

Table 3
Geological formations

Basins	Amount of water recharged (10^6 m^3)	Water level below land (m)	Aquifer thickness (m)	Velocity (m/yr)	Abstraction ($10^6\,m^3$/yr)
Sahara Nile	136	30–100	300–500	1–2.5	7.3
Sahara Nubian	20.6	10–50	300–500	0.8–1.5	1.5
Central Darfur	47.6	25–100	250–550	0.3–6.0	5.5
Nuhui	15.4	75–120	200–400	1.0–2.75	1.6
Sag El Na'am	13.5	50–1000	300–500	1.0–25.0	2.5
River Atbara	150	100–150	250–300	0.3–5.0	2.3
Sudd	341	10–25	200–400	0.1–1.8	1.8
Western Kordofan	15	50–70	300–500	0.1–0.3	1.7
Baggara	155	10–75	300–500	0.1–2.4	11.9
Blue Nile	70.9	10–50	250–500	0.1–2.5	10.2
The Alluvial	N.A	Shallow	N.A	N.A	N.A
Gedaref	41.7	50–75	200–500	0.1–2.0	1.2
Shagara	1.1	25–30	200–300	0.1–2.5	0.7

50% of the irrigable land of the country. However, agriculture has to compete with other municipal and industrial uses.

The annual flow from the local seasonal streams, which do not flow to the Nile, varies considerably from one year to another (The range from 3 to $7 \times 10^9\,m^3$/yr). The amounts of renewable groundwater have not yet been measured accurately, but it is estimated to be $4 \times 10^9\,m^3$. When including the share of the international waters, the amount of fresh water at the country's disposal would be 906 m^3/caput. This is below the water stress limit of 1000 m^3/caput. The average annual yield of the Non-Nilotic streams is estimated at about 7 km^3/yr, of which 5 km^3/yr are internally produced. The major streams are the Gash and Baraka in the east of the country, both of which are characterised by large variations in annual flow and heavy silt loads.

Groundwater is found in many parts of the country, but generally in formations of considerable depth, ranging from 40 to 140 m (Table 3). Moreover, recharge is rather limited and the aquifers are found under regions distant from the infrastructural facilities. The aquifers that are easily accessible like Gash basin in the east and Nyala basin in the

west have been seriously drawn down and water quality has deteriorated considerably. The ground water quality is suitable for animal and human consumption as well as for agriculture and other uses. The potential renewable ground water suitable is estimated at $6 \times 10^9\,m^3$. The main aquifer is Nubian sandstone covering 28% of surface of the country. Groundwater is mainly used to satisfy animal and human needs in rural areas while small areas are irrigated from groundwater. About $5 \times 10^9\,m^3$ may be used for agriculture during the coming 10 years. Current use for both agriculture and drinking water is about $1.2 \times 10^9\,m^3$. The groundwater potential is believed much more than presently estimated.

The major groundwater formations and basins are the Nubian Sandstone Basin and the Umm Ruwaba Basins. The Ghazal, Sudd and Sobat swamps in the south of the country represent major wetlands, from which evaporation is exceptionally high. According to an estimate from 1980, the extent of the Sudd is over 16,200 km^2, but the surface area fluctuates with rainfall. Sudan's total natural renewable water resources are estimated to be 149 km^3/yr, of which 30 km^3/yr are internally produced. In a 10th frequency dry year, the internal water resources are reduced to about 22.3 km^3/yr. Of the internal water resources, 28 km^3/yr are surface water and 7 km^3/yr are groundwater, while the overlap between surface water and groundwater is estimated at 5 km^3/yr. As a result of the Nile Waters Agreement with Egypt, total actual renewable water resources of the country amount to 64.5 km^3/yr.

3. Water use

Water demands in Sudan extends beyond agriculture to industry, which is mainly agro-based, to electric energy—mainly hydropower; to trade, transport, health and the environment. Sudan is under-populated, with an average population density of 13 persons/km^2, but more than half of its people live on just 15% of the land, which is the area adjacent to the Nile. Ninety-four percent of the presently abstracted water in Sudan goes to agriculture, 5% to human and animal consumption and 1% for industrial and other uses.

Gezira, Rahad, Suki and New Halfa are the 4 largest national schemes of the country. They cover more than half the currently irrigated area and consume 60% of the present Sudanese annual water abstraction (Fig. 1). Annual abstraction from the Nile has been fluctuating between 13 and $16 \times 10^9\,m^3$ for the last 20 years. The overall efficiency for irrigation in Sudan is generally high (85% for Gezira), which consume 40% of the present abstraction of the country. The main headache is siltation and aquatic weed growth in the canals and the deterioration condition of the irrigation infrastructure.

Present power generation is lagging behind demand, with clear evidence of suppressed demand and low standby generation. However, there are many potential sites for hydropower generation on the main Nile and its tributaries in the east, and south. Although hydropower does not consume water, storage causes an incremental increase in evaporation losses. Annual incremental increase in evaporation losses from dams proposed for hydropower may exceed $6 \times 10^9\,m^3$.

Evaporation and evapotranspiration is generally high, ranging from 1000 to 3000 mm/yr. One hectare of seasonal crop requires 12000 m^3 of water if planted once per year. Hence, $30 \times 10^9\,m^3$ available from internal and external water resources will irrigate 2.5 million ha, which is 1% of the country's area and less than 5% of its arable land. If some of the area were planted to perennial crops or used for more than 1 seasonal crop per year,

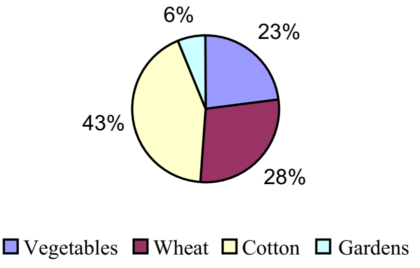


Fig. 1. Irrigated agriculture in Sudan.

the irrigated stress situation is bound to become even worse. Reduction of evaporation losses from the swamps in Southern Sudan is bound to have adverse effects on the local society and the environment. The situation is worsened by the fact that more than 80% of these waters flow in spates during the flood season, loaded with silt and debris and causing serious problems for the limited storage facilities, pumps, turbines intakes and irrigation networks.

Navigation, fisheries and recreational activities are yet to be explored fully. Water requirements for human and animal consumption are bound to increase with time as a reflection of the expansion in urbanisation and industrialisation. A recent study of expected abstraction up to the year 2020 gives a figure of 69% for agriculture, 18% for industrial and hydropower requirements and 13% for human and animal needs [5].

4. Water privatisation in Sudan

Today, access to clean water is increasingly considered a basic human right. Water has become a defining sustainable development issue uniting a range of Non-Governmental Organisations (NGOs) and activists, and cutting across interests from the environment to human rights, women's rights and anti-globalisation. Nor is the impact of water scarcity limited to such often-cited countries as Egypt and Sudan. Around the world, the privatisation of water and sanitation services is a hotly contested debate, and the role of national governments in the negotiation of water sharing rights continues to be controversial. Critics claim that United Nations (UN) set targets will result in further privatisation and in water not being available to poor communities unable to pay. The pro-privatisation camp, meanwhile, argues that the poor already pay up to 10 times more than the rich for water in many countries, that someone has to pay and that only the private sector can make the necessary investment.

The process of allowing private sector participation in the provision of water has generated concerns and debates about the wisdom of privatising a vital public utility such as National Water Cooperation (NWC), Sudan. Concerns range from the obvious lack of transparency in the process to that of the impact of privatisation process have argued that water is so basic to the very existence of the individual that its availability in the community should not depend upon corporate boardroom decisions. Very poor and poor communities spent 8% and 12% of the monthly incomes, respectively on water, while non-poor households spent 4.6% of their monthly incomes on water (Fig. 2). Water policies require that communities not only contribute to the installation of capital equipment, but also bear all recurrent costs including repair and maintenance costs.

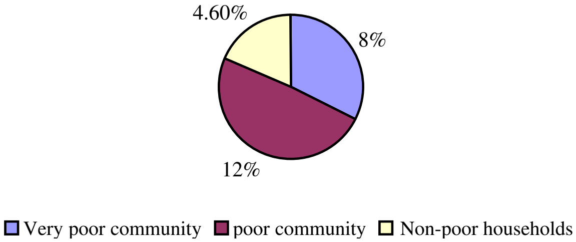


Fig. 2. The impact of privatisation.

4.1. The usurpation of policy making in Sudan

Donor and creditor agencies have been highly influential in the processes of privatisation, liberalisation and de-regulation in Sudan. In general, the privatisation initiatives are the legacy of the structural adjustment policies adopted and implemented by successive governments under the World Bank (WB) and the International Monetary Funds (IMF). The available information suggests that current reforms aimed at privatising water and electricity have been designed to meet reform schedules agreed with the WB and the IMF. For instance under the terms of the 1994 enhanced structural adjustment facility (ESAF), the government was required to proceed with privatisation of a number of state corporations, including the NWC, Sudan. Furthermore, bilateral and multilateral loans and grants have been made conditional upon the privatisation of essential public services such as water, railways, electricity and banking. Structural adjustment has meant trade and economic liberalisation, which entails the deregulation of economic activities and privatisation. Thus, the government has had to liberalise exchange rates, decontrol prices, reduce tariffs on imports, relax rules and regulations on investment and privatise state enterprises. It is expected that, as time goes on, some new issues will surface while earlier issues will fade out. When this happens, another review of the water sector policy would be appropriate.

4.2. Implications

Business has a key role to play in managing these pressures on water resources. It accounts for 22% of water use globally and is responsible for up to 60% of water withdrawal in some high-income countries. While the outcome of the debate on water privatisation will have direct impacts on the strategy of water companies, water scarcity impacts all businesses. The key implications for business include:

- *Business continuity*: Decreasing supply of water at the levels of quality required could severely impact the ability of a company to operate.
- *Cost*: Prices are likely to rise as water is increasingly privatised. Reduced supply and more stringent legislation may also drive up prices.
- *Government controls*: Legislation is increasingly targeting the volume of water used, the source it comes from, the quality of discharge and so on. Meeting such requirements will be key for the company to remain in compliance.

- *Water-dependent product sales*: Products that depend on users having access to clean water will also suffer decreased efficacy and potential loss of sales as the availability of clean water decreases.
- *Employees*: In some regions, the impact of water shortages or low water quality on local employees will be marked. Results may include increased absenteeism, decreased morale and failing productivity due to illness.
- *Community frictions*: A company's local licence to operate may also be questioned as local communities and civil society increase scrutiny of companies' water management systems.
- *Reputation and brand value*: Both are especially vulnerable, given that local activism on water issues can have global impacts.

Environmental effects usually go beyond national borders. Hence regional joint efforts are required to address them (such as joint applied research and training, exchange of information, consensus concerning control measures, regional integrated projects, and the like). Eco-efficiency in the form of reduced water use; recycling and reuse—will enable companies to decrease expenditures on water purchase and treatment. Steps to manage impact on water include:

- Articulate a global water policy including clear objectives, standards and key performance indicators.
- Identify facilities and sites that are currently or likely to be in water stressed areas and implement the water management strategy in these areas as a priority.
- Commission a life cycle analysis for all products from upstream suppliers through to downstream customer impact and focus on the process that has the most impact.
- Engage with stakeholders at a global and local level.

4.3. Legislation

In 1992, the national economy was reoriented towards a free economy, a policy shift that impacted the agricultural sector profoundly. The government withdrew from the direct financing of agriculture, provision of inputs and services. The Government within its policy of withdrawal from provision of goods and services handed over all the small- and medium-size irrigation schemes under its control to the farmers. The handing over policy was not successful because farmers were ill prepared and most of the schemes were in need of rehabilitation. Since 1992, the cropped areas and the productivity of many schemes have sharply declined.

Many laws and regulations have been draughted over the years to deal with the use and protection of the water resources systems. These include the following:

(1) The Nile Pump Control Act 1939
(2) The River Transport Act 1950
(3) The Fresh Water Fisheries Act 1954
(4) The Water Hyacinth Control Act 1960
(5) The Public Health Act 1975
(6) The Environmental Health Act 1975
(7) The Regulation of Inland River Navigation Act 1980

(8) The Irrigation and Drainage Control Act 1990
(9) The Gash Basin Water Development and Utilisation Act 1992
(10) Wadi Nyala Water Development and Utilisation Order 1993
(11) The Water Resources Act 1996

Agricultural sectoral policies for the irrigated sub-sector include the following:

- To extend the market economy to all crops to allow the farmer to choose a suitable crop mix.
- To provide support to the agricultural research institutions so as to explore suitable technologies for improving crop production and productivity. In addition, to provide support to agricultural extension and services.
- To encourage the private sector to provide agricultural inputs for the agricultural sector.
- To encourage exports through improvement of quality so as to meet international standards.
- Establishment of specialised crop committees for main crops like cotton with the objective of achieving all necessary coordination between the concerned authorities.
- Farmers participate in agricultural policy formulation.

The Sudan Comprehensive National Strategy for the Agricultural Sector (1992–2002) put food security, sustained agricultural development, efficient resource utilisation and yield enhancement on the top of the agenda. Little has been done, however, to improve the accessibility to food of the poor, the vulnerable and the marginalised strata of society.

4.4. International dimension

As the Sudan shares water resources with all its neighbours, its water policy has to reflect this international dimension. This article shows some of the joint efforts to establish and advance cooperation with the Nile basin countries for the integrated development of the shared watercourse. Initial steps have been taken heading for the joint management of other common surface and groundwater resources. The first step was putting the monitoring, assessment, planning, management and development of all the surface and groundwater resources under the Ministry of Irrigation and Water Resources (MOIWR). The second step was the formation of the National Council for Water Resources (NCWR), which includes representatives from all stakeholders of the wide water sector. The third step was the decenralisation, privatisation and active participation of users in the management and funding of the water schemes.

Sudan is central within the 10 Nile basin countries. All the major tributaries meet inside Sudan and the Nile flows then to Egypt as a single river. The three major non-Nile systems (Gash, Baraka, and Azoom) are shared with neighbouring countries. The Nubian Sandstone aquifer is shared with Chad, Egypt and Libya. Thus any national water resources policy is bound to affect and be affected by the policies of those countries sharing the same water resource systems. A joint advisory committee was formed recently between Sudan and Ethiopia for the exchange of information and bilateral efforts, especially in watershed management, wildlife protection and hydropower linkages. Some work has

started with Chad for water harvesting along the shared watercourses. Groundwater assessment for the Nubian Sandstone aquifer has started jointly with Egypt and Libya. Sudan will continue to support, activate and enhance cooperation with its neighbours, especially in water sector affairs.

4.5. Decentralisation

In 1994, the Government of Sudan began to implement this policy in order to devolve certain fiscal, administrative and development responsibilities from the central government to the state assemblies. Most rural states have since indicated severe distress, largely due to difficulties in raising sufficient revenue to address poverty in these areas. The expectation that these rural communities will provide substantial backup funds for decentralised water projects has proved unrealistic. While decentralisation can increase participation, accountability and transparency, the desire to reduce central government expenditures and increase the revenue generation responsibilities at the state level. The decentralisation process, therefore, set the stage not only for devolving to the states the responsibility for the provision of drinking water and sanitation services, but also shifted some of the responsibility for the government's international debt burden repayment to the impoverished rural and semi-rural areas.

In 1994/1995 fiscal years, the government began to implement decentralisation policy to segregate the potentially profitable urban water supply systems from the unprofitable rural water systems. The same policy also shifted responsibility for sanitation and wastewater management to the impoverished local governments. The WB prescribed the policy of segregation (unbundling) in order to create a segment of the water sector that would be attractive to, and profitable for, foreign private investors [6]. This process is sometimes called cherry picking or cream skimming. Prior to the segregation policy, there existed an integrated water sewerage system, which ensured that drinking water and sanitation were managed together. It also facilitated cross subsidies. The relatively better resourced metropolitan and urban communities together with industry paid a small levy to support government delivery of water to the relatively poorer rural communities. The segregation policy has destroyed all that. The result is that less endowed local governments are unable to meet the water and sanitation needs of their people. Also, the segregation of rural water from urban water ensures that the majority of the people who live in the rural areas will not benefit from the expected 'efficiency miracles' expected from the proposed management service contract.

5. Utilisation of water resources

Agriculture is by far the largest water user in Sudan. Improvement in agriculture techniques and water use efficiency is desperately needed. The irrigated area in Sudan is about 4 million feddans, which uses about 70% of the allocated share of the Nile waters. It must be stressed that:

- Less than 20% of the discharge of the Nile is "timely water".
- Silt has influenced considerably the design and operation of dams.
- The present water demand, for Egypt and Sudan, is close to the maximum sustainable level.

- The population growth is undoubtedly faster than agricultural expansion and production.

It is relevant to state that the management of the Nile waters has historically been staggered and sectoral. Biased short-term national interests and narrow disciplinary professional polarisation were the overriding constants, disregarding the international character of the river and the nature of its finite resources. The Nile Basin should be developed and managed as a single indivisible whole, within a long-term integrated outlook. Rivarian countries should complement each other rather than compete for shared resources.

According to the 1993 census, 65% of the urban population have access to piped water [7], whereas only 20 of the rural population enjoy the same facility (Table 4). Other sources give much lower figures. The Government National Programme of Action for Child Survival and Development sets availability of 20 l of safe water per capita per day, within 1 km from the users' dwelling, as the acceptable standard. A clear national definition of what a safe source of water is, has yet to be adopted.

Urban populations theoretically consumes 20 l per capita per day while rural people get 8 l at two and a half times the cost per litre. Variations are large from one place to another. People in Darfur consume less than one-fourth of those in Khartoum. Population in pre-urban areas and in newly emerging urban centres are around 35% of the total urban population and generally do not have access to safe water. The quality of urban water supply is questionable [8]. Surface water sources are contaminated and bear heavy loads of suspended silt. Waterworks are old and small and cannot cope with the escalating demand. Increased reliance on ground water in the past few years has partially released pressure off in the way of quantity but not quality. Septic tanks and soak-away wells are a constant threat of contamination.

Distribution networks are old and is a potential weak link taking up contaminants, in the case of the capital Khartoum for example. Increased reliance on booster pumps and storage tanks have contributed to the depletion of the major power supply as well as offering excellent breeding sites for mosquitoes. The worst-case scenario is the city of Port Sudan; suffering from chronic water shortages on the one hand and the heavy incidence of malaria on the other.

Table 4
Percent population with access to sources of water

Sources of water	Northern states	Southern states	Rural	Urban
Pipe connection	19.62	65.81	35.33	7.02
Boreholes	56.12	20.25	43.93	55.16
River/canal	14.09	2.25	10.05	30.01
Tanker	4.78	0.59	3.35	0.24
Haffirs/Fola	1.36	7.17	3.34	5.40
Others	3.97	3.82	3.92	1.74
Not stated	0.06	0.11	0.08	0.43
Total	100.0	100.0	100.0	100.0

Source: [7].

The celebrations of the city of El Obeid with the new source of water from Bara, was short lived. The old distribution system soon collapsed. Storm drains is another fiasco. It is a paradox that there is no clear link between the water supply and sanitation sectors. Even within the water sector there are poor linkages between the Federal and state water corporations. The water sector itself has experienced ten major institutional changes since independence.

The Sudanese National Plan of Action (NPA) sets the goal of universal access to safe drinking water and sanitary means of excreta disposal by the turn of the decade [8]. The Comprehensive National Strategy gives priority to the following strategies for achieving the set:

- Cost-effective utilisation and management of water resources.
- Introduction of low-cost appropriate technologies and encouragement of local production of equipment.
- Rehabilitation of deteriorating water sources and systems.
- An expanded programme of well-drilling and hand-pump installation, especially in priority rural areas.
- Training, capacity building and increased use of domestic technical resources, to increase cost efficiency and reduce dependence on external resources.
- Development and expansion of sanitation services.
- Increased community involvement in planning, execution and management of water supply and sanitation services encouraging cost sharing and self-help.
- Encouragement of research aimed at better water resources management, evaluation of existing schemes and identification of cost-effective alternative strategic elements.

The National Comprehensive Strategy gives priority to the rural sector, emphasising rehabilitation of existing water yards, expansion of low-cost technology options (hand pumps) and improvement of surface water sources (water harvesting, haffirs, etc.). The priority in urban areas is to restore existing waterworks to their original designed output followed by rehabilitation of other sources and expansion of services especially in Khartoum and the 16 state capitals recently upgraded from towns to cities (Table 5). Only 40% of the urban population have access to safe water. Investment does not match growth in needs. The State Ministry of Housing and Public Works of Khartoum conceded, "The

Table 5
Rural water sources

Type	Number	Capacity (m^3/day)	Installed actual yield
Water yards	4252	447,000	146,000
Hands pumps	8000	48,000	32,000
Dug wells	7000	56,000	44,800
Haffirs/dams	856	142,000	56,800
Slow sand filters	233	16,500	8200
Total	20,441	710,000	287,800

Source: [7].

Table 6
Urban demand for water

Region	Capacity (m^3/day)	Demand (m^3/day)	Coverage (%)
Khartoum	350,000	700,000	50
Northern	30,000	64,000	47
Eastern	48,000	205,000	20
Central	80,000	184,000	39
Kordofan	23,000	114,000	17
Darfur	14,000	74,000	20
Southern	20,000	103,000	16
Total	565,000	1,445,400	39

Source: [7].

estimated deficit of clean water supply in Khartoum is about 40,000 m^3/day''. The unaccounted for losses in the distribution system are as high as 40% (Table 6).

Globally and regionally a realisation is setting in that constraint of freshwater resource availability and their sharing could be a major impediment to security and subsequently to sustainable development of developing countries. Scarcity of freshwater resources globally is fast becoming a major factor in limiting the development of regions and in causing conflict between regions sharing the same water resource. The Nile has many origins, draining 10% of the African continent's river water and flows 6825 km through three climatic zones and 10 sovereign countries. The Nile flowing through Sudan is the confluence of two major rivers. The White Nile and the Blue Nile, which merge near Khartoum, the Sudan capital.

The National Water Act of 1994 (Law No. 1155) defines the objectives, principles, and instruments of the National Water Resources Policy and the National Water Resources Management system. The law establishes the institutional arrangement under which the country's water policies are to be implemented. The National Water Resources Policy was proposed to achieve: (1) Sustainability: to ensure that the present and future generations have an adequate availability of water with suitable quality. (2) Integrated management: to ensure the integration among uses in order to guarantee continuing development. (3) Security: to prevent and protect against critical events, either arising from natural causes or inappropriate uses. To achieve such objectives, water management must be implemented according to the following principles: (i) water is a public good; (ii) water is a finite resource that has economic value; (iii) the use of water required to meet people's basic needs shall have priority, especially in critical periods; (iv) water management shall comprise and include multiple uses; (v) the river basin is the appropriate unit for water management; and (vi) water management shall be decentralised, with participation by government, stakeholders and society.

To fulfil the overall objective of water resources planning and management, in order to enhance the development and implementation of effective national water policies and strategies for integrated water resources management (IWRM), Sudan has successfully produced a ''National water Policy'' document in the year 2000. A workshop was convened and the policy was adopted. The policy, however, should have adopted a comprehensive framework and should have treated water as an economic good.

Greater attention should have been given to pricing and the fuller participation of stakeholders. Relevant concepts that could have been considered include:

- Adopting an analytical framework
- Institutional and regulatory systems
- Incentives
- Water conserving technology
- Poverty alleviation
- Participatory approach
- Environmental protection
- Skill upgrading

The Water Resources Act was passed in 1995 and the National Water Resources Council was formed. It made reference to stakeholders, research, pricing, licensing brick making, river transport vessels and water abstraction. It failed, however, to mention wetlands, erosion, drainage, standards, water harvesting, water related diseases, rainwater as a resource, etc. The act concerned itself with freshwater only as it does not mention the Red Sea and its bountiful marine resources.

The Nile Basin Initiative process matured in May 2001 by adopting both the Initiative and the Common Vision. This is a Strategic Action Programme involving basin-wide projects in addition to sub-basin joint projects. These are seven broad-based programmes:

- The Nile Trans-boundary Environmental Action
- Nile Basin Regional Power Trade
- Water Resources Planning and Management
- Confidence Building
- Stakeholders Involvement (Communication)
- Applied Training
- Socio-economic Development and Benefit Sharing

Concurrently, countries of the "Eastern Nile" and those of "Equatorial Lakes region" have identified joint projects (Subsidiary Action Programmes). Basically, the Nile Basin Initiative is a country and needs-driven programme. It should be stressed here that the Nile should have been treated as one indivisible whole. Historically all control works and projects have been carried out where and when the need arose. Engineers and diplomats were the only players and other stakeholders were never involved. The not unexpected consequence is that six of the Nile Basin countries are among the poorest in the world [9].

Today's advanced societies heavily depend on energy. The sources of energy and electricity generation today in Sudan are waterfalls, natural and artificial, and fossil fuel. Energy from waterfalls is short of meeting the current or future energy requirements, and the fossil fuel resources, being depleted with time, will eventually run out. For human civilisation to continue at its natural pace, new forms of affordable and clean energy must come on line. Failure of human civilisation to introduce new forms of energy will render that civilisation doomed, and the quality of life will deteriorate. If this unlikely scenario actually takes place, the requirements will decrease because the mechanism of making it available for use (pumping) diminishes. The more likely scenario is more optimistic one, and it is that a new form of energy generation will be introduced in which case water

desalination becomes affordable and its pumping from the coastal desalination plants become possible at reasonable cost. The way out of the looming water crisis rests, therefore, in the invention of new forms of energy generation that will make possible the reliance on desalination and in the recycling of wastewater for reuse in agricultural production and for environmental reasons. Integrated management of the three resources of water, energy, and the environment, will result in better results with a positive sum for society (Appendix A).

6. Environmental issues

It has been reported that the number of people living in Sudan urban areas is increasing rapidly. It is estimated that by 2015 about 30% of Sudan's populations will be urban. In big and small urban centres alike, low-income settlements account for 40–60% of the population [9]. Provision of safe drinking water and adequate sanitation in these settlements has been identified as an issue of great concern. Informal settlements are characterised by lack of adequate physical planning, low socio-economic status, poverty-stricken population, overcrowding, inadequacy of water supply, lack of privacy (shared bathrooms and toilets), hazards environmental conditions and poor access by vehicles and pedestrians. Sudan urban authorities and central governments have approached provision of water and sanitation services to these areas differently, with varying degrees of success.

Rivers and streams flowing down from the Ethiopian highlands and those seasonal ones originating inside Sudan sometimes flood the fertile plains around them and may erode their banks, causing loss of life, property and agricultural land. As flood protection and bank stabilisation could be costly. An early flood warning system was recently put in place in the MOIWR. Although the system has not been completed to its full extent in equipment and coverage. It proved to be a very helpful tool in mitigating the effects of flood in 1994 and 1996 [10].

Constructions of dams and storage reservoirs have their environmental impact on the local community and the aquatic ecosystem. Deposition of silt and debris, build up of aquatic weeds and changes in water quality in reservoirs and irrigation canals may increase water-related diseases. Application of chemical fertilisers, insecticides and herbicides in irrigated agriculture may cause pollution of water bodies. Water hyacinth and tsetse fly in the wetlands of the south impose an unhealthy environment for human and animal life. At the same time, reclamation of these swamps is bound to have environmental impacts on the fauna and flora, domestic livestock and wildlife and the livelihood of the inhabitants. Municipal and industrial wastes from the developed parts of the country, which are on the increase, may cause environmental hazards if not treated properly. Drought spells and the accompanying desert creep, losses of vegetal cover and deforestation have far-reaching environmental effects. Some unsolved issues, which might dictate the direction for Sudanese water policy in the new century:

6.1. Sanitation

Sanitary means of excreta disposal in the way of sewerage systems are scarce. Pit latrines are the predominant facility. Only parts of Khartoum enjoy a water-based sewerage system, constructed in the early 1960s. It is overloaded and is overtaken by the vertical and horizontal expansion of the city. The Khartoum north sewerage system was never

commissioned. Ventilated improved pit latrines (VIPs) have been introduced in rural area as part of UNICEF-assisted water supply and sanitation project. VIPs cover the needs of 6% of the rural population of northern states of Sudan. Eastern states of Sudan have no access to any sanitary facilities. Affluent residential areas in urban centres use pit-latrines and soak away wells. As mentioned above this poses an obvious threat to ground water quality. Public latrines are almost nonexistent. Uses of open-air latrines are only too common with the obvious consequence of surface water contamination. This is particularly felt with the onset of the rainy season.

According to the WHO, about 90% of major epidemics in Sudan are water-borne or water related. These come in the form of Diarrhoea, viral hepatitis, malaria, bilharzias and guinea worm, whose incidence constitute 90% of global incidence. Some 40% of infant mortality is due to diarrhoea. The Federal Ministry of Health estimates that 7–8 million individuals are infected by malaria annually. Only 40–60% of these cases are reported and facilities are up to 35%. A social cost that has to be paid is the burden of fetching water in rural areas. This is the responsibility of women and girls. During the rainy season they collect water from rain-pools, tube wells, haffirs and seasonal streams. In the dry season they might have to walk for much longer distances to get to the contaminated sources. The walk could take from 4 to 8 h and could use one-third of their daily nutritional intake, undermining their health. Sometimes young girls are forced to drop out of school to help their mothers. Polygamy is sometimes encouraged in order to spread out the tedious burden.

Other uses of water include:

- *Industry*: It has been estimated that it amounts to 1% of the water use in Sudan. This is mainly in the sugar industry, mining, dairies, tanneries, slaughterhouses, refineries, soap and oil production.
- *Hydropower*: The present installed capacity is 280 MW at Roseires, 15 MW at Sennar and six at Khashm el Girba. The potential in the Sudan may exceed 9000 MW. Siltation and evaporation are the major constraints.
- *Navigation*: The River Nile and its tributaries are only partially and seasonally navigable. The White Nile is navigable all year round from Khartoum to Juba. Unfortunately, the River Transport Corporation has almost totally collapsed in the not very far past. It can barely manage to run passenger ferries across the rivers. The private and traditional sectors have become rudimentary.
- *Fisheries*: Sudan had a coastline of 750 km on the Red Sea and over 6400 km of river waters covering an estimated 2 million ha. Lakes Kundi, Keilak, Abyad and Dariba form the group of natural lakes while Sennar, Roseires, Khashm El Girba, Jebel Aulia and lake Nubia form the group of man-made lakes. Sudan also enjoys some of the largest wetlands in the world. In the Nile Basin as a whole wetlands cover at least a hundred thousand km^2 or about 3% compared to 2% forest and 1.4% irrigated croplands. Stretches of rivers near large markets are over-fished while many others are under exploited. It is not irrelevant to mention that management practices at Khashm El Girba dam (flushing the silt) has depressed the quantity of fish as well as its biodiversity in the River Atbara. The reservoir has only 10 species of fish as opposed to the 106 species found in the Nile within Sudan.
- *Recreation*: Is almost never accredited as a use.

6.2. Coastal environment

The Red Sea is a semi-closed sea. It is linked to the Gulf of Aden over a 100 m sill at Babb el Mandeb. The Suez Canal connects it to the Mediterranean. It takes 30 years for the complete exchange of its waters to the north and south. The Red Sea is saline and shallow and does not receive the flow of any major river. It is vulnerable due to extremes of temperature and salinity in addition to the fact that it is the major highway of the oil traffic. It is bordered by nine countries whose influence on the coastal and marine environments varies in quality and quantity. The Red Sea does not experience high tidal activities. Fringing reefs as well as a barrier one line the coast. It has numerous islands and many bays and lagoons. The maximum depth of the sea is about 2000 m and the deeps are characterised by a myriad of currents and gyros. It is rich in minerals and biodiversity but is not one of the important commercial fishing grounds of the world.

The Red Sea is a unique and complex marine ecosystem. It is an extraordinary rich biological diversity and a high degree of endemism. There are also well-developed mangrove stands. Seagrass beds cover large areas, in the sheltered coastal lagoons and bays. The Sudanese coast has the most diverse coral reefs of the Red Sea [11], and one of the largest atolls in the world. Negative impacts also include the destruction of coastal habitats by dredging, reclamation and construction works, anchor damage to coral reefs, breakage of corals by divers, land-based pollution (as well as that from marine traffic), overexploitation of fish and shell fish and disturbance to wildlife, such as turtles and birds.

Sudan is a member of the Regional Organisation for the Conservation of the Marine environment of the Red Sea and the Gulf of Aden [11], a regional effort, supported by the Global Environmental Facility (GEF) to protect the marine and coastal environment of the Red Sea and to promote compatibility and a balance of use. The project also aims at concentrating at defined issues concerning coastal management; carry out prior assessment of the impacts of major projects as well as promoting issues such as national resources and environmental accounting.

6.3. Pollution

Industrial activities in Sudan suffered a series of setbacks. Only 30% of the established factories can be considered as operational. These are mainly food and sugar industries. The other light industries, mainly in Khartoum North, El Baggier, Wad Medani and Port Sudan, have almost been grounded to a standstill. Almost all are neither connected to any form of sewerage system and did nor adhere to internationally adopted standards of pollution abatement, inside or outside the factories. There are no statistics available as to the solid, liquid or gaseous effluents, in spite of available legislation and local regulations (i.e., Atbara and the Nile Cement factories). Very little is known on the large new complex of GIAD industrial city at El Gedid, 45 km south of Khartoum.

Effluents from sugar factories flow freely into the Blue and White Niles, in spite of the presence of legislation prohibiting that. The air of some cities is much more polluted than what we would like to believe. Khartoum is a striking example:

- Prior to the use of Sudanese fuel, we used to import whatever we could, in the way of price and quality. No standards were adhered to as to the octane quality or the amount of antiknock added.

- There are no standards enforced on the permissible exhaust emissions.
- The several thousand feddans (1 feddan = 1.38 acre or 0.42 ha) of "greenbelt" around Khartoum have been transformed into residential neighbourhoods, the thing that depressed the carbon sequestration capacity of the city. Furthermore an appreciable percentage of the private farms and ranches along with the large agricultural schemes, like Gammouiya, Seleit, Soba, El Waha; have been abandoned.

They were no longer economically profitable under the prevailing policies.

- In the past few years thousands of two-stroke powered "rickshaws" went into the public transport business. They are notoriously environmentally unfriendly. Commissioning thousands of three-piston-powered mini-vans to the public transport sector has further aggravated this.
- In the meanwhile the brick industry, the second largest consumer of biomass fuel, had been on a steady in if not appreciating mode.
- The largest source of pollution is El Gaili refinery, 40 km north of Khartoum. It is unfortunate that about 90% of the butane gas produced is burnt out at the refinery. The storage, export and household capacity are still minimal.
- There are three thermal generating stations in and around Khartoum: Kilo-10 (gas), Burri (Diesel) and Khartoum North (furnace). Needless to stress that they are very close to and in the case of Burri in the heart of residential neighbourhoods.
- Immediate plans include a Malaysian financed 260 mega Watt (MW) diesel station in Kilo 10 and a Chinese financed 210 MW at El Gaili.

It is, however, pleasing to report that the governor of Gedaref State, after enforcing a total ban on the use of plastic carrier bags, instructed his local authorities not to renew licences of restaurants using charcoal or firewood. Only gas operators will be allowed to carry on. At the Federal level, the new Minister of Agriculture recently issued a number of decrees to protect the depleted forests, like banning the trans-state transport of firewood and charcoal.

6.4. Pesticides

Some 85% of the pesticides imported are used intensively and extensively in the Gezira Scheme. Organo-chlorines have been banned since the early 1980s. There are many forms of strict controls of the use of pesticides, starting with the Pesticides Committee, registration procedures, storage, etc. The situation remains far from perfect. Pesticides somehow find their way to the local markets, and waterways, etc. Sudan has large quantities of obsolete pesticides, getting rid of which is still an unsolved problem.

A new use for pesticides was discovered in Sudan that of hunting wildlife. In the 1970s and 1990s, villagers around Dinder National Park were able to obtain large amounts of meat by poisoning some water points in the Park. The meat was sold at the local markets.

Aerial spraying of Khartoum State has become a matter of routine in the past few years. The name and concentration of the pesticide(s) used were never disclosed to the public. No Studies were made on their impact on target species (mosquitoes) and housefly and non-target species (humans) were ever carried out acute or chronic.

Mining activities in the eastern Sudan have been employing arsenic compounds for extracting gold. Are the used chemicals and tailings, disposed of safely? The same question was asked of the pipeline coating plant at Sinkat town in the late 1990s. No answers were given. These examples are to demonstrate that the general policy adopted is defiantly not transparent. The notion of sustainability does not seem to find any audience.

The largest source of air pollution in Sudan is, without question, the dust storms. They are so common (and increasing in frequency and intensity). That Sudanese do not seem to see the water under the bridge or the wood in the forest.

7. Globalisation

It is heart-warming that the UN Committee on Economic, Social and Cultural Rights has adopted the General Comment on the right to water, referring to article 11 of the International Covenant on Economic, Social and Cultural Rights. The General Comment states that "The human right to drinking water is fundamental for life and health. Sufficient and safe drinking water is a precondition for the realisation of all human rights." This means the provision of water must be adequate for human dignity, life and health. The adoption of the General Comment is significant in that it means that households can no longer be disconnected from water supplies. Such a disconnection will be in violation of international law. Official governmental recognition of the right to water and sanitation, as an integral component of the body of human rights that have already been internationally recognised, would basically require states to give greater attention to the water supply problems of the most disadvantaged members of society. Inequality is growing as the price of water, among other things, is steadily increasing beyond the reach of many.

It is especially important in Sudan context to protect wells and the sources of drinking water of persons who are not connected to the water supply system. Water wells in highly populated areas like Khartoum, Gedaref, El Fasher, El Obeid, Kassala, Port Sudan, etc. must benefit from quality control measures currently limited only to piped water. This will improve the availability of drinking water by making these wells safe sources of drinking water. Ultimately all urban homes must be piped. It is also important to install free water points and public fountains in public schools, hospitals and poor communities. The anticipated health dividends in such an investment will be a reasonable trade off and the ultimate reduction in the health budget should make such an investment appealing to any government that cares for its poor including the workers who produce and distribute the water. The direct impact on the workers of the Sudan National Water Corporation is no less traumatising. Many have lost their jobs since the privatisation began in the mid 1990s. It was expected that the local authorities would hire most of them after transferring the sanitation and wastewater management to the local authorities under the decentralisation and separation policy. For the most part, this did not happen because, on the one hand, there was no contractual obligation on the part of the local governments to take them on and, on the other, because the local governments had no means to pay them.

It is time to make the issues of water and sanitation the focus of policies. We need to respond to these problems politically. We work to alleviate poverty among the poor when we should be demanding their right to a decent living, health, education and participation in policy formulation as citizens. Policies with the potential to exclude the poor especially women, children and the disabled should not merely be condemned but vehemently resisted. The work of most NGOs appears to be directed towards mobilising sympathy,

instead of organising for change. We advocate for change, but we are not often at the centre of organising and fighting for change. We complain of the effects of one policy or the other on the poor, women and children but we are often not prepared to engage politically to address the power imbalances that make this possible. This must change if we want results.

7.1. Spectres of prepaid water metres

Prepaid metres are a violation of human rights. It may be efficient in enhancing revenue collection but it is socially insensitive and exclusive. In anticipation of privatisation, a NWC is installing prepaid metres on a pilot basis in some parts of Southern Darfur (Nyala, El Deaein, Buram) (Fig. 3). Poor people may not have enough money to prepay for an adequate supply of water. Most people in affluent societies live on credit and not even the rich prepay for their trinkets. Should the poorest of the poor prepay for water to feed the greed of a handful of shareholders?

Some major changes took place recently when Sudan adopted a free market economy, privatisation and decenralisation system. Farmers' associations have now the upper hand in the funding and management of irrigated schemes. Operation, management and development of water supply for small-and medium-sized irrigated schemes are totally under the responsibility of the local community. Cooperatives and the private sector are encouraged to own and operate such schemes.

As a supply-oriented policy is capital intensive and is limited by the availability of water, a mixed policy of supply and demand management has to be followed. The policy should target the improvement of water use efficiency, revision of cropping patterns and selection of crop varieties to produce more with less water. Integrated water resources planning and management, research and training at all levels and public awareness of the value of water are important tools to support the demand-management approach. Other tools could be



Fig. 3. Water prepaid metres on a pilot basis in Western regions.

the regular monitoring and inspection of canals and hydraulic structures, and the enforcement of regulations against water wastage, coupled with incentives and penalties as appropriate. Applied research should be encouraged to address the problems of sedimentation in reservoirs and canals, aquatic weeds in canals and drains, appropriated technology to improve water use efficiency and mitigation of floods and droughts. Active participation of water users in decision-making should be encouraged to foster ownership feelings, facilitating the application of any decisions. Users should be trained to shoulder the operation, maintenance and replacement of the water facilities within their domain.

7.2. The right to an adequate water

While the debate continues at the international level on whether or not globalisation can bring benefits to the world's poor, the fact remains that the deepening inequalities of income and opportunity between and within nations has led to an increase in the number of people without adequate water supply. Every women, man, youth and child has the human right to secure clean water to live in peace and dignity. Several macroeconomic factors influence the availability of resources for social spending, including:

- small or even negative return from trade liberalisation by developing countries, particularly least developed countries;
- financial volatility following deregulation of capital flows coupled with interest rate hikes, which affect access to credit and mortgages;
- heavy burdens of debt servicing; and
- the process of public sector reform, particularly through decentralisation and privatisation.

The consequences of having inadequate or no access to water are devastating, especially for women and children. When water is not readily available it is particularly the women and children who have to spend a large amount of time fetching water back to their houses. This has detrimental impact on their health, security and education. Women and girls carry the bulk of the burden in providing water for households in rural areas and often have to walk great distances in search of water to meet minimal household needs (Fig. 4). Also, with increasing opportunities for women to engage in productive employment activities, their time increasingly carries monetary value. In many instances, if this cost is included in the decision-making about the choice of technology and strategies for household water security, it will be found that in rural areas women and girls are paying far more for water than they do in urban areas. The lack of access to clean and sufficient water and sanitation facilities contribute to diseases, which result in more expenses and thus perpetuate the vicious cycle of poverty and diseases [12].

Several authors, politicians, leaders of international organisations and journalists have cautioned the world community to the fact that the increasing scarcity of freshwater resources might lead to national and international conflicts [13]. These predictions are not new: water scarcity is often related to future war. The cooperative water resource management faces several obstacles such as the critical nature of water for human existence, the multiple use of water, the sheer scale and the gap between policies and implementation of these policies. However, many institutions, which govern the



Fig. 4. Girls carry the bulk of the burden in providing water for households' daily need.

management of transboundary water resources point to the fact, those in many river basins countries are able to overcome their differences and cooperate to the benefit of all.

8. The future look

As water is a part of every thing, it is too large to be contained under one umbrella. The MOIWR is responsible for monitoring, assessment, development and management of the Nile waters and some other major shared streams, like Gash and Baraka. Responsibility for other streams and drinking water facilities used to be under other ministries. In a major step towards closer coordination, these responsibilities together with groundwater affairs were brought within the responsibilities of the MOIWR at the start of this decade. Meteorological data and information are catered for through a public corporation under the Ministry of Aviation. There is close coordination between this public corporation and the MOIWR. Major step was taken for the formation of the National Council for Water Resources (NCWR), and it included representatives of the stakeholders from supply and demand sides, legal, financial, international relations, research and training and the related private sector. The main objectives are to formulate common water resources development policies, strategies, plans and legislation, guide and supervise their implementation, coordinate and integrate the activities of all the water sector agencies and stakeholders and preside over international affairs related to water.

Sudan is a large country with varying standards of living, culture and climate. When this is superimposed on the multi-sectoral nature of water, coordination of activities in water resources important in that direction. The specialised committees in the council have to explore the means for optimal usage of water and the tools and regulations to guide and control those means. It might be helpful to have affiliated councils or branches at state levels, where water availability and quality are major issues. Monitoring of the application of policies and strategies should be institutionalised through an adequate inspection and feedback system.

The country's water policy has evolved over the years in accordance with changes in supply–demand relationships and the dynamic character of the water sector. Looking from

the supply side, it is now curtailed by the limited storage capacity on the Nile and the seasonal streams, and the high cost for pumping groundwater. Some measures are currently being taken to address this problem. It includes heightening of Rosaries dam and the halted construction of Jonglei canal. It is recognised there is an environmental dimension to such projects, which has to be catered for. Nevertheless, more dams have to be built, especially for water harvesting from seasonal streams. Future advancement in technology may render groundwater monitoring and abstraction and non-conventional water resources economically feasible alternative options.

The sprit of cooperation and close coordination with countries sharing the same water resources should continue, preferably through an institutional cooperative framework for each shared basin. The guiding spirit should be equitable, legitimated, integrated, sustainable and environmentally sound utilisation of the common water resources, without significant harm from one country to another. If a water sector policy extends beyond a certain planning horizon, the uncertainty would be too high to be ignored. The main reason is the wide spatial coverage of water and the number of variables involved. This future look was focused more on the issues, which emerged recently. When a policy is put into practise, it should be monitored to advance the benefits and treat the drawbacks. New issues are expected to emerge in the future and some of the existing ones may peter out. A water sector policy is bound to be reviewed from time to time in response to the results of previous policies, lessons drawn from them and the surfacing of new issues.

9. Recommendations

One of the main concerns is the unequal access to freshwater resources at the national level. Although privatisation measures in the water sector are not necessarily negative with respect to the water demands of the population. The challenge is to come up with practical strategies and ideas for improving access to adequate quality water and safe sanitation for serving the un-served poor. The following actions for improving access to safe water and environmental sanitation services.

9.1. Policy

- Government must officially recognise that informal settlements will remain around for a long time, and therefore put in place short, medium and long-term strategies for addressing poverty in this context.
- Government must firmly embrace and enforce physical planning statutes to curb the mushrooming of informal settlements and to bring some order in the existing ones.
- Further, the government must address rural poverty, by improving services and employment opportunities in the rural areas in order to reduce rural–urban migration.

9.2. Partnerships

Government ministries responsible for water and environmental sanitation must spearhead the formation of informal settlement partnerships and open up dialogue with civil society organisations, communities and donor agencies around the issues of access to basic services, among them water and sanitation.

9.3. Small-scale independent providers (SSIPS)

- The role of the SSIPs in the provision of water and sanitation services to the urban poor can no longer be ignored, and policy makers must create enabling environment for SSIPs to offer better services.
- The enabling environment must address, among other things, financing and legal backing of the SSIPS operations.
- The water and sanitation programmes (WSP) must come out of the box, formalise and regularise the SSIPs as legal partners in service delivery and in as far as possible, seek to strengthen their capacities.

9.4. Innovative technologies and approaches

- Research, recommend and promote appropriate management models for increasing access to water and sanitation by the urban poor.
- Research, recommend and promote appropriate technologies for use in informal settlements. Such technologies must address acceptability, affordability and sustainability.

9.5. Training and capacity building

Communities, SSIPs working in the informal settlements must be capacity-built with a view to making them understand their roles, rights and responsibilities in service provision. The capacity building must also address community resource mobilisation and organisation of community groups.

9.6. Financing

- The central government budgetary allocations should be driven by the MDGs needs, with programmes that are specially meant to benefit the urban poor.
- Research and develop appropriate financing models, exploring such avenues as rolling funds, cooperatives, self-help groups and micro-credits for financing small-scale water and environmental sanitation projects in the informal settlements.

10. Conclusions

Booming economy, high population, land locked location, vast area, remotely separated rural areas, which are not easily accessible, large reserves of oil, excellent sunshine, large mining sector and cattle farming on a large scale are factors which are most influential to the total water scene in Sudan. Water resources plans are developed to guide future decisions and are to be developed for each river basin and state, as well as for the country. The overall objective is to coordinate efforts and establish guidelines and priorities for water allocation and water pricing. The priorities established for water allocation would be used in critical drought conditions. The water quality classification of water bodies by different classes of use is the basis for truly integrating the quality and quality of water management. Water pricing is the single most controversial instrument of the law. The pricing system recognises the economic value of water, as stated in the principles of the

policy, but is also the most difficult step to implement. It is expected that the pace of implementation will increase and the quality of work will improve in addition to building the capacity of the private and district staff in contracting procedures. The financial accountability is also easier and more transparent. The factors affecting the eco-environmental changes are complex. There are interrelated and interact. The deterioration problems of water and sanitation have attracted some attention in recent years. There is an urgent need to study possible rehabilitation measures to ensure a sustainable and excellent water quality and improved sanitation. When the expected impacts of climate change increasingly become reality, will government be able to address the challenges at the national and international levels without resorting to resource capture? Will the government be able to formulate a coherent framework with policies and instruments, which reduces structural forms of water scarcity?

Appendix A

For descriptive formulae used in the study see Table A1.

Table A1
The descriptive formulaes

Main criteria	Sub-criteria	Formulae
Food	Grain security	$\sum_{It=1}^{N} \frac{\text{Grain production } (t/y)}{\text{Required grain consumption } (t/y)}$
Economic	Value added	$\sum_{i=1}^{N}\{\text{Return (SD)} - \text{Cost (SD)}\}$, where N is the number of sectors (agriculture, industrial, domestic water supply, navigation, power generation)
Water	Water security	Water security = [total available water resources−total water requirements] ($10^6\,m^3$/yr)
	water sustainability	$\sum_{i=1}^{K} \frac{\text{Volume of water used from resource}}{\text{Potential of resource}}$, where K is the number of water resources (surface water, shallow groundwater, deep groundwater, desalination, etc.)
Socio-economic	National employment	$\sum_{i=1}^{K}$ Total employment of sector$_I$, where K is the number of sectors (agriculture, industrial, domestic water supply, power generation and navigation)
	New settlers	Total homes tender of agriculture sector
	Land per capita	$\frac{\text{Total cultivated land}}{\text{Total population}}$ (ha/capita)
	Water per capita	$\frac{\text{Available water resources}}{\text{Total population}}$ (m^3/(capita yr)
	Shisto paracities prevalence	Shisto paracities prevalence = number of shisto patients over the country
	Typhoid paracities prevalence	Number of typhoid patients over the country

Table A1 (*continued*)

Main criteria	Sub-criteria	Formulae
Environmental	Agro-chemical *per capita*	$\sum_{i=1}^{N}\frac{\text{Pesticide used in (kg/yr)}}{\text{Population}}$, where N is the number of pesticide used all over the country
	Industrial effluent integrated water quality index	Integrated water quality index for sewage or industrial wastewater $\text{PT}i=\frac{\text{APLP}i}{\text{SP/P}i}$; $\text{IWQ}I=\frac{1}{K}\sqrt{\sum_{i=1}^{i=K}\text{P}I_i^2}$, where PT$i$ is the population index for parameter K, APLPi the actual population loads of parameter K, SPLPi the standard pollution load of parameter K, $\text{IWQ}I_{S/I}$ the integrated water quality index (S the sewage wastewater, I the industrial wastewater), K the number of proposed water quality parameters
	Domestic effluent integrated quality index	Same as above

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